with kind regards.

ON THE DISEASES KNOWN AS "BARK CANKER" AND "DIE BACK" IN FRUIT TREES.

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INTRODUCTION.

The term "Die Back" appears to be of American origin and according to Stevens and Hall (20) it was first used by Rolfs in 1907 to describe a disease of peach and Japanese plum trees in Missouri. The name "Die Back" was descriptive of some symptoms of the disease which was characterised by a wilting and killing of twigs and branches which commenced at the tips and progressed downwards to the larger limbs.

Considerable literature has accumulated on the subject of "Die Back" disease in different host plants as the result of work published both in England and abroad. The following is a *résumé* of the papers published by workers in England in the order in which they appeared.

As far back as 1902 Massee (15) described the disease occurring in nursery stock of Apple, Plum and Pear. He attributed the disease to the fungus *Eutypella prunastri* Sacc. and stated that he had obtained positive infections with the spores of the fungus. In the many specimens of diseased plants, belonging to different hosts, examined during the last eighteen months, the writer has found no trace of the fungus *Eutypella prunastri* Sacc.

In 1912 Wormald (23) published an account of the disease as it occurs in Cherry trees. He stated that although his observations suggested that *Cytospora* sp. was a parasite, they by no means proved it since inoculation experiments with mycelium and conidia from pure cultures are essential. His inoculation experiments with mycelium and conidia yielded negative results.

In 1915 Belgrave (1) described a disease or diseases of plum trees believed to be caused by one or more species of *Cytospora*. Inoculation experiments examined a year later showed no signs of infection.

In 1920 Wiltshire (22) working on the disease in plum trees, started to investigate the relationship between the bacterial masses and *Cytospora* sp. both of which he found present in the diseased tissues. At the same time he (21) described the Bark Canker Disease in Apples.

Three years later (1923) Miss Gilchrist (5) working on apple material from the same source, also described more fully the bark canker disease said to be caused by the fungus *Myxosporium corticolum* Edg.

Shortly afterwards, in July, 1924, Miss Cayley (2) published a very full account of " Die Back " disease as it occurs in stone fruit trees. Knowledge of " Die Back " in fruit trees in England was advanced very considerably as the result of Miss Cayley's work. For the first time the fungus *Diaporthe perniciosa* Marchal was described as being associated with, and said to be the cause of, " Die Back " disease in stone fruits in this country.

The most recently published work in this country on a " Die Back " in trees is an account by Day (3) of the Watermark disease of Cricket Bat Willow said to be caused by a short rod-like schizomycete which the author has provisionally called Bacterium salicis. The fungus *Cytospora* sp. is found closely associated with this disease but the author points out that the lowering of the physiological condition of the tree is undoubtedly necessary before this fungus can attack.

A boring beetle has also been found associated with the disease in the cherry and more often in plum. Field observations, however, show beyond doubt that this insect is late even as a follower of the primary cause or causes of this disease.

Of the foreign publications only those which are directly concerned with " Die Back " in fruit trees are referred to at this stage. Those dealing with " Die Back " in other trees will be referred to below.

In 1910 Rolfs (18) working at the Missouri Fruit Station, published an account of the Winter Killing of Twigs, Cankers, and Sunscald of Peach Trees. The organism mentioned in connection with the disease in Missouri is *Valsa leucostoma* (Pers.) Fr. var. *cincta* Rolfs.

In 1919 Stevens (19) described an apple canker in Illinois said to be due to *Cytospora*.

In 1921 Leonian (13) published his studies on the *Valsa* Apple Canker in New Mexico. As will be seen later, the *valsa* fungus with which this author worked is the same as the *Cytospora* studied by Stevens (19).

It will be observed that various organisms are said to be the cause of one and the same disease. Another striking fact is that in no case were inoculation experiments really successful in reproducing the main features of the disease. To produce local infections with one or more organisms inoculated into trees grown or treated unfavourably does not justify the statement that the organism—used for inoculation is the primary cause of disease.

It is not proposed to give detailed descriptions of the fungi *Myxosporium corticolum* Edgert., *Cytospora* sp., and *Diaporthe perniciosa* Marchal, in this paper since full accounts of these organisms have previously been given by Miss Gilchrist (5), Wormald (23) and Miss Cayley (2) respectively.

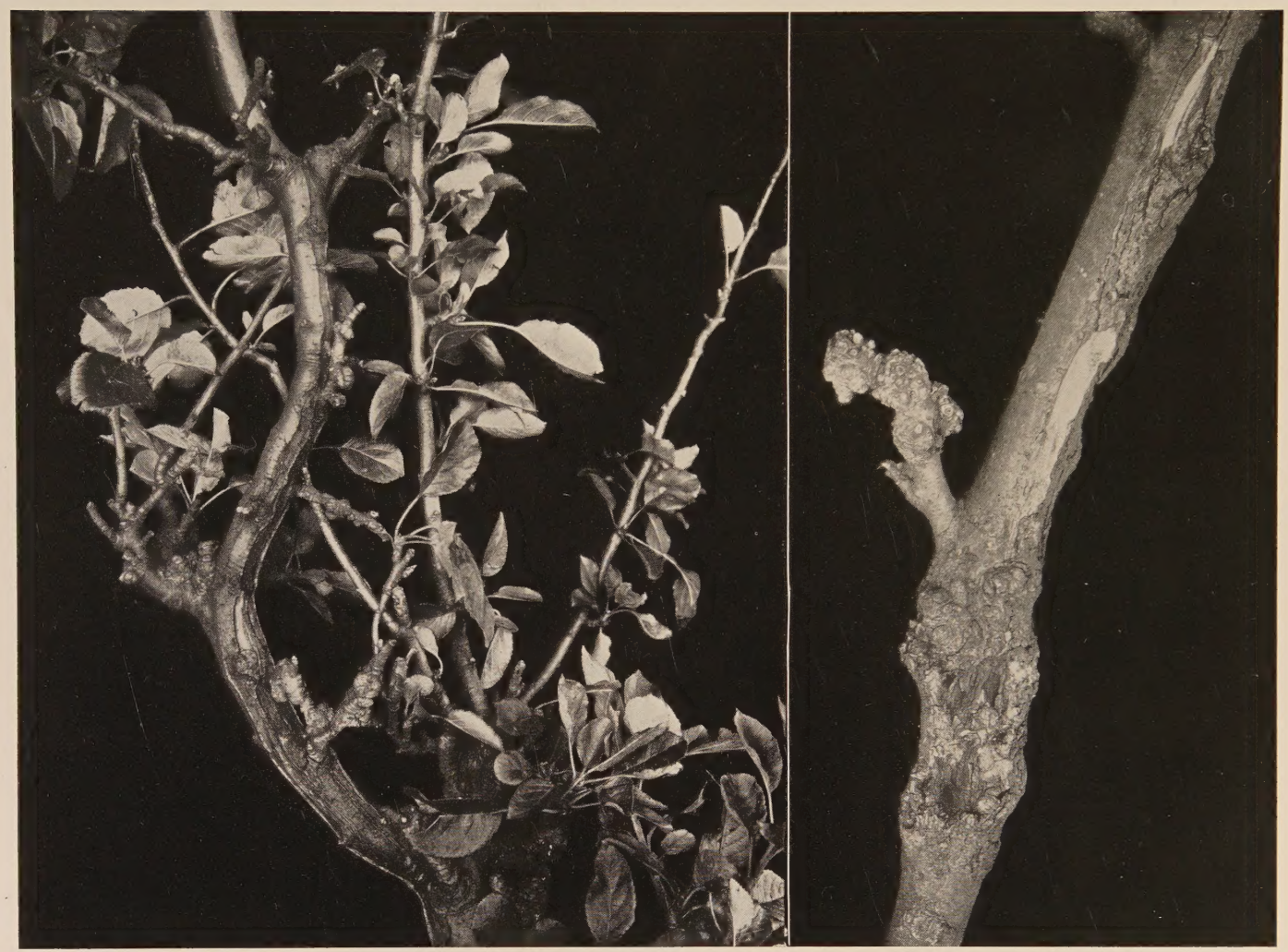
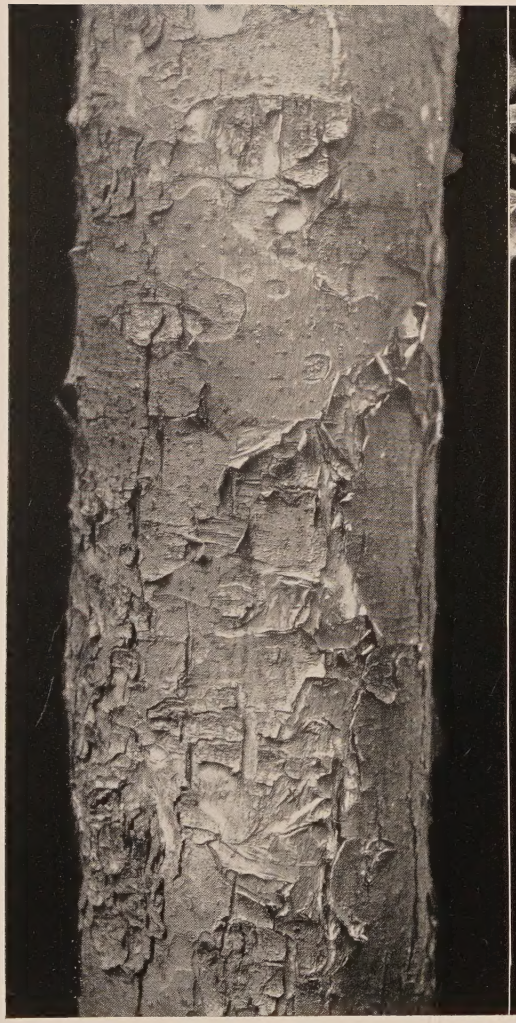


FIG. 1.

FIG. 2.

PLATE V.



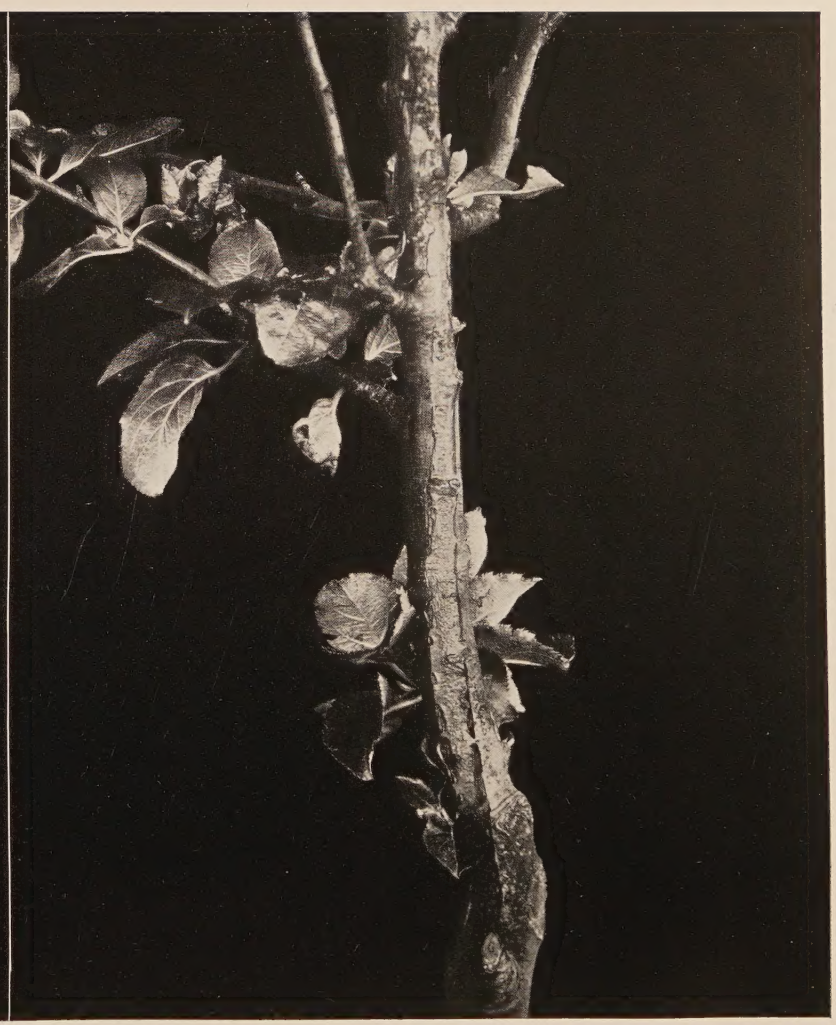


FIG. 1.

FIG. 2.

PLATE VI.

OBJECT OF INVESTIGATION.

In the United States (11) the fungus *Myxosporium corticolum* is responsible for the superficial bark-canker of the apple and the pear. The fungus mycelium grows in the outermost bark tissues only, and it does not reach the cambium. Its progress into the tissues is arrested by a layer of cork developed by the plant in response to the stimulation induced by the invading fungus. The affected tissue is killed and eventually it sloughs away. Fruiting bodies, acervuli, are formed just beneath the surface of the bark. The damage caused by the fungus is so slight that it is doubtful if any remedial measures are ever necessary or profitable.

Wiltshire (21) followed by Miss Gilchrist (5) working on a " Die Back " disease of apple trees came to the conclusion that it was due to *Myxosporium corticolum*. There is considerable difference between the disease as described by them and the Superficial Bark Canker of the United States, although the causal organism in both cases is the same. In England the wood is affected, whereas in the United States only the outer cells of the bark are affected, hence the name Superficial Bark Canker. To indicate this difference both Wiltshire (21) and Miss Gilchrist (5) called the disease Bark Canker, and omitted the word Superficial, since it did not apply in England. This has led to some confusion, since the disease in England is a " Die Back " and its cause, as will be shown later, is the same as " Die Back " in other fruit trees. The present paper has as its object the clearing up of the confusion between Superficial Bark Canker, Bark Canker, and " Die Back " in fruit trees, both in regard to the primary causes of the disease on different hosts, and the control measures to be taken against the disease.

THE DISEASE IN APPLE AND PEAR TREES.

The external appearance of the disease in apple trees is characterised by a longitudinal splitting on each side of an area of bark $\frac{1}{2}$ to $1\frac{1}{2}$ inches broad. The disease progresses very rapidly and in a few weeks the splitting of the bark may extend for the whole length of a main branch five to six feet in length (Plate V, Figs. 1 and 2). The disease may start at any portion of the branch and in one case developed on the trunk of the tree just above soil level. In the latter it caused the rapid death of the whole tree, whereas in the former individual branches are killed one after the other. In contrast with the extremely rapid advance of the disease in a longitudinal direction is its very slow development transversely. Girdling of a limb is very slow. The bark between the two longitudinal splits later becomes sunken owing to the skrinking of the underlying tissue and the cessation of growth of the wood in the affected region due to the death of the cambium. The wood underlying the sunken area of bark is

brown in colour to varying depths up to half an inch or more. Microscopic examination shows the presence of fungus hyphae in the cortex, wood vessels, and medullary rays. As the bark is killed it invariably becomes covered with small raised black specks. These specks are the fructifications (acervuli) of the fungus *Myxosporium corticolum* Edgert. When mature a tiny slit appears in the bark at the centre of each speck. In moist weather the spores of the fungus (Plate VIII, fig. 2*d*) are liberated through the tiny slits and can be seen with the naked eye as white points. These are washed down the branches and trunks of the trees by rain. After the spores have been liberated, the acervuli appear as tiny, black, elongated, and shallow pits. As stated by Miss Gilchrist (4) the disease is active only towards the end of the summer. The symptoms and development of the disease on pear trees is similar to those on apple trees. The bark splits longitudinally and is always followed by the production of innumerable acervuli of the fungus *Myxosporium corticolum* Edgert. The underlying cortex and wood take on a brown discolouration and are invaded by fungus hyphae. In spite of the extremely regular occurrence of the fructifications of *Myxosporium corticolum* on the diseased bark of both apple and pear, it is difficult to regard this fungus as the cause of the disease. Over a dozen cultures have been made from time to time from the innermost diseased wood underlying the sunken bark of several affected branches and on no occasion has *Myxosporium corticolum* been obtained in cultures. The fungus which grows in cultures of such diseased wood is always *Diaporthe perniciosa* Marchal. Cultures from the outermost diseased wood yield generally a mixture of *Myxosporium corticolum* Edgert, and *Diaporthe perniciosa* Marchal. When the disease has advanced and the tissues are drying up pycnidia of *Diaporthe perniciosa* are often produced on the bark. Both *Myxosporium corticolum* and *Diaporthe perniciosa* produce conidia in culture. In the many cultures of *Diaporthe perniciosa* grown from diseased apple wood and the pycnidia on the bark which the writer has always found to contain "a" conidia only, the fungus generally produces pycnidia with "a" type of conidia only but in a few cases, both "a" and "b" types have been obtained in cultures made from "a" pycnospores. The "b" type as well as the "a" type are often formed by the fungus isolated from the plum, pear, and Cherry Laurel (Plate VIII, Fig. 2*a* and *b*). The "a" conidia of *Diaporthe perniciosa* resemble somewhat in shape those of *Myxosporium corticolum*. The former, however, are much smaller, being only 7-9 × 2-3 μ, whilst the conidia of *Myxosporium corticolum* measure 16-39 × 5-11 μ. The fungus *Myxosporium mali* Bres. mentioned by Miss Gilchrist has not been found by the writer. Mr. R. M. Nattrass and Mr. F. E. V. Smith have subsequently made cultures from the innermost diseased wood on apple and pear trees. As with the writer the fungus was found to be *Diaporthe perniciosa* Marchal. In view of the results obtained by culturing the underlying wood Mr. Smith

and the writer together made a detailed examination of the bark of apple and pear trees in the plantations at Long Ashton. They found that *Myxosporium corticolum* occurs on the bark of all varieties of otherwise healthy apple and pear trees which are twenty or more years old. Subsequent examinations of apple and pear trees throughout the western counties also showed that *Myxosporium corticolum* is always to be found on the bark of older trees.

SUPERFICIAL BARK CANKER.

The fungus *Myxosporium corticolum* as it occurs on the bark of otherwise healthy trees, agrees with the above description of the Superficial Bark Canker (11) and (24) in the United States. The fungus attacks the outer bark of the trunk and larger limbs generally, but sometimes occurs on the damaged bark of the younger branches. The disease can be recognised at some distance by the reddish or bronze colour and the slightly sunken appearance of the portion of bark attacked. The affected areas range in size from small areas of a few millimetres only in diameter to large patches measuring several inches across. These patches often coalesce and eventually the whole trunk is covered, so that it is extremely likely that the normal roughening of the bark in mature apple and pear trees in this country is due, in great part, to the activities of this fungus. Affected areas become covered with the innumerable fructifications of the fungus (Plate VI, fig. 1). The fungus hyphae never penetrate beyond the few outer layers of the bark cells, and as is found in America, it never reaches the cambium. The affected layer of bark is separated from the healthy by cork cambium which afterwards becomes suberised. Later, the outer bark can be easily peeled off with the hand. As a disease it does not warrant consideration by the grower and it is questionable whether the fungus is not, in some cases at any rate, beneficial since it gives the softer tissues underlying the outer bark a chance to expand in growth, thereby lessening the danger of the tree becoming bark-bound. Growth splits which occur in branches and trunks of trees in some seasons often become infected with *Myxosporium corticolum*, but its activities are confined to the outermost layers of bark. This stimulates the tree to the formation of corky tissue underneath and this quickly closes a wound which otherwise might be open to infection by a serious fungus parasite such as the silver leaf organism (*Stereum purpureum*), or the canker fungus (*Nectria galligena* Bres.). Cases of infection of growth splits by the latter fungus have been observed.

The following infection experiment on apple trees using *Mxyosporium corticolum* and *Diaporthe perniciosa* separately, and together, as inocula has been carried out. The variety of apple trees used was James Grieve. In all cases a slit in the bark and wood was made with a sterilised scalpel, and mycelium from pure cultures of the fungi was introduced with a sterilized needle and the

wound was then bound with raffia. Six trees were selected and six branches of each used for the experiment. Five branches of each of the trees were inoculated and the sixth branch served as a control in each case. The branches of two of the trees were inoculated with *Myxosporium corticolum :* the branches of two others were inoculated with *Diaporthe perniciosa :* and the branches of the remaining two with mycelium of both *Myxosporium corticolum* and *Diaporthe perniciosa.* The two fungi were used together because, at the time, it was thought that possibly one of the two fungi paved the way for the other, although any one of the two alone could not produce the disease. None of the inoculations succeeded in producing symptoms of the more serious disease of " Die Back," formerly known as Bark Canker, which is characterised by the longitudinal splitting of the bark. In almost every case including the controls and those inoculated with *Diaporthe perniciosa* only, fructifications (acervuli) of *Myxosporium corticolum* developed on the injured portion of the bark. This infection experiment gave negative results in spite of the fact that inoculations were made at the end of August, 1923, at which time of the year the disease commences to become active again. The negative result of this experiment is very significant. Observations of the disease as it occurs in the field show that in all cases where the disease occurs on apples and pears, the trees are in an unhealthy condition from some cause or causes before infection by *Diaporthe* can take place.

The Disease in Stone Fruit Trees.

As in the case of apple trees the symptoms of the disease vary according to the point at which the disease commences. If it starts at a wound on a branch the same longitudinal splitting and sinking of the bark is noticeable, particularly in the plum, although the bark does not split to anything like the same extent in stone fruit trees as in apple trees. In all the host plants callus is formed by the healthy tissue bordering on each side of the sunken area of diseased tissue. The bark of the diseased area takes on a reddish colour and eventually becomes covered with the fructifications of *Cytospora* sp., or *Diaporthe perniciosa,* or more commonly with a mixture of both, particularly in the plum. Where extensive bark splitting does not occur the branches become somewhat flattened on one side. This is due to the cambium being killed on one side, and therefore further production of wood at this region is impossible, whereas growth continues in the unaffected portion of the branch. The splitting of the bark is usually accompanied by an exudation of gum. The wood, below the sunken area of bark is brown to more or less an extent depending on the degree to which the disease has developed.

Microscopic examination shows the presence of gum in the tissues, particularly the wood vessels and medullary rays. Fungus hyphae may or may not be found present in the vessels of the wood. It has been observed that

vessels whose cavities are completely filled with gum or tyloses do not contain fungus hyphae. This is so marked that it strongly suggests that fungus hyphae cannot penetrate readily through the gummy substance. Wound gum is probably, therefore, a deterrent to fungus infection. Branches and trunks of trees of all ages are subject to the disease. In the case of young trees which are generally attacked in the main stem the fungus *Diaporthe perniciosa* usually gains entrance at the point of union of stock and scion, and sometimes through a large and incompletely healed wound. The disease girdles the stem and the tree dies from below upwards. In the field generally the first noticeable sign of the disease is the sudden browning and wilting of the leaves in midsummer and soon afterwards the tree is killed. Later, the diseased areas become covered with fungus fructifications. These often develop whilst the branch or tree is still alive provided the disease is confined to one side only. If the branch or trunk is completely girdled fructifications appear after the tree has been killed. Several organisms are found in association with the disease on stone fruit trees. These include the fungi *Cytospora* sp., *Diaporthe perniciosa*, and in the case of few of the plum trees examined *Myxosporium corticolum*. In the case of one plum tree about eight years old the fungus *Cryptosporella prunicola* Oud. was found. The identification of this fungus was made for the writer by Miss E. M. Wakefield at Kew. Owing to the fact that the perithecia of this fungus were found very closely associated with the pycnidia of *Cytospora* sp. it was at first thought that it might be the perfect stage of *Cytospora* sp. Cultures of both, however, proved beyond doubt that this was not the case. Only the perithecial, stage of *Crytosporella prunicola* Oud. were found. Masses of rod-shaped bacteria which agree with those described by Wiltshire (21) are also found in the plant tissues. These bacteria are generally confined to the area between the healthy and diseased tissues and are exuded as light yellowish beads when the overlying bark is pressed with the thumb. As previously stated, it is at these points that the splitting occurs. What appear to be the same bacterial masses occur in peach and cherry as well as in the plum. Attempts to grow the bacteria in pure culture on artificial media have failed. These bacteria have not been observed on apple, pear or Cherry Laurel suffering from the disease. The only organism which is constantly present in diseased tissue in all host plants is *Diaporthe perniciosa*. On young plum trees the fructifications of *Diaporthe perniciosa* are generally confined to within a few inches of the area whence the disease started which in the majority of cases is low down on the stem at a wound or the point of union of stock and scion. The main stem above is covered with the fructifications of *Cytospora* sp. Plate VII, figs. 1 and 2 shows the same disease as it occurs in the Cherry Laurel (*Prunus Lauro-cerasus*). Portions of the sunken area of the bark of the Cherry Laurel were carefully incubated and examined for fungus fructifications and the only ones found were the pycnidia

of *Diaporthe perniciosa*. Both Mr. Nattrass and the writer made several isolations from the diseased wood and except where contamination by species of Penicillium occurred all yielded pure cultures of *Diaporthe perniciosa* to the exclusion of *Cytospora* sp., *Myxosporium corticolum* and bacteria. From the above it seems more than likely that, under certain conditions, the fungus *Diaporthe perniciosa* can produce the disease in all the host plants mentioned without the aid of bacteria, *Myxosporium corticolum* or *Cytospora* sp. On the other hand, the writer considers that although the fungus *Cytospora* sp. is a weaker parasite than *Diaporthe perniciosa* it, nevertheless, is sometimes independently, but more often following *Diaporthe perniciosa* a contributing factor in the killing of the plant. Furthermore, the evidence of this paper proves that *Diaporthe perniciosa* although the stronger of these two, is, nevertheless, also a weak parasite and cannot infect a healthy tree, but only those seriously enfeebled by one or more factors such as those discussed below. The general impression of the writer is that the bacteria are not pathogenic, but their presence cannot be entirely ignored. If at some future date they are proved to be weakly pathogenic it will make no difference to the conclusion drawn in this paper.

Evidence of Weak Parasitism of Diaporthe Perniciosa.

On Apple Trees.

The row of apple trees (James Grieve) on which the disease has mostly been studied by Wiltshire (21), Miss Gilchrist (5) and the writer, are twenty years old, planted ten feet apart with the same distance between the rows, and main branches are covered with large *Nectria* (Plate V, fig. 2) and Scab cankers, as well as American blight. Furthermore, the variety is a heavy cropper and the trees have, of late years, purposely not been freely manured. The trees were, in the first place, planted for intercropping purposes between standard orchard trees, but it was decided later to keep them as material for experimental purposes. The fruit and leaves borne are small in size for the variety, which is another clear indication of lack of vigour. Wiltshire (21) also remarked on the poor condition of these same trees. Some of the branches have been cut back from time to time and have become infected with *Diaporthe perniciosa* which under these conditions is capable of becoming a serious parasite. There was not sufficient vigour in the trees to push out the dormant buds below the point to which the branches were cut back. Had the trees been able to do this, the probability is that, they would not have contracted the disease to any serious extent. The disease has also been observed elsewhere on pear trees about twenty years old which were completely neglected during the war, and are badly attacked by both canker (*Nectria ditissima*) and Scab (*Venturia pirina*). During the war no cultivation of any kind was done and since then they have received very little manure. Several young trees of different varieties were

FIG. 1.

FIG. 2.

PLATE VII.

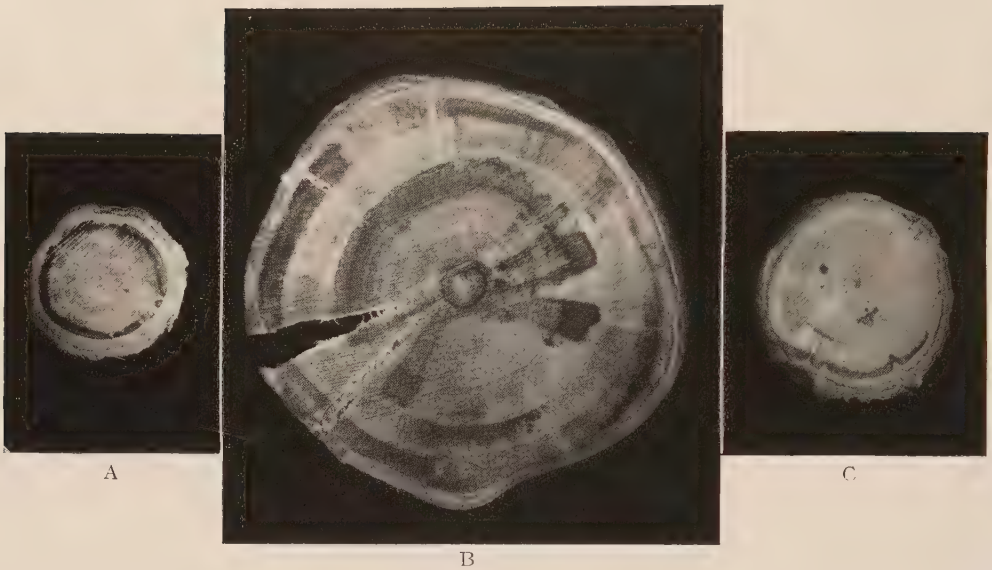


FIG. 1.

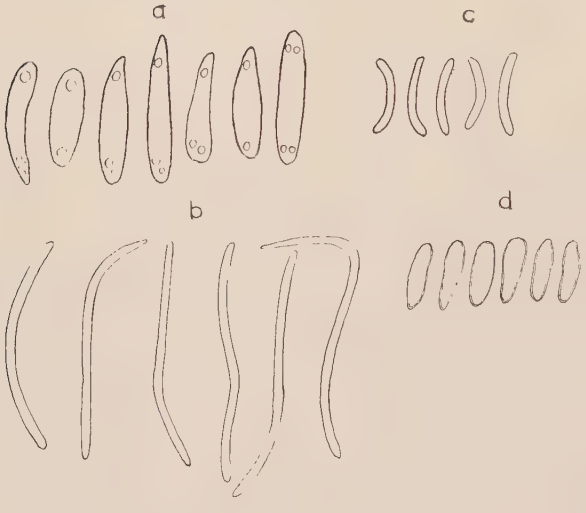


FIG. 2.

PLATE VIII.

pruned in the early spring of this year and since then they have been under close observation. In the normal course of events the pruned end dies back as far as the next bud below it. The great majority of these snags became infected with different fungi including *Diaporthe perniciosa* and *Cytospora* sp., but, nevertheless, the twigs did not as a rule die back further than the next bud. In rare cases the twig or branch died back to the second bud, and was infected to this point with *Diaporthe perniciosa*, *Cytospora*, and other fungi. The cause of this was invariably found to be due to damage of the uppermost bud. The trees in question were robust, and healthy plants which had been liberally and regularly manured. Similar observations have been made on fruit trees elsewhere. The disease never progressed further than the point at which a new shoot was formed. If *Diaporthe perniciosa* and/or *Cytospora* sp. are the primary cause of disease it is difficult to understand why they do not kill the branches after gaining entrance into the tissues.

Three young apple trees which had been growing in pots for three years were transplanted into the open in the spring of this year. Early in June, when the trees were in leaf they were given, with other foodstuffs, a dressing of sulphate of ammonia. One of the trees was inadvertently given too heavy a dressing with the result that the roots were damaged and a few days later the leaves turned brown and the tree was defoliated. The tree later put out a fresh crop of leaves, but before it had recovered from the drastic treatment of three years of pot life, a transplanting in the spring, followed by severe root damage due to the sulphate of ammonia, it contracted the disease described above (Plate VI, fig. 2). The disease did not appear in the other two trees which remained comparatively healthy.

Apple trees are subject to a dying back of twigs and branches said to be due to *Cytospora* sp. The writer has never found this form of "Die Back" disease except in cases of trees or individual branches enfeebled by some other disease or physiological disturbance.

On Plum Trees.

Early in the summer of 1923 two unusually tall standard plum trees (some of the stems 7 ft. 6 ins. in height) about nine years old, were sent to the writer from the Evesham district. The trees were dying, although the uppermost branches were still living and were bearing yellowish green leaves. Very little growth had been made in that year. The lower part of the main stems were dead and covered with pycnidia of *Cytospora* sp. and *Diaporthe perniciosa*. The roots were all brown, dead and water-logged. The condition of the root system suggested bad dainage. The trees were seen by Mr. Locke, Foreman of the above Station, who recognised the trees, on account of their exceptionally tall stems, as some he had planted some years ago in a low lying and badly drained

orchard near Evesham. Mr. Locke states that, at the time of planting, he was convinced that they would not do well in that orchard. The soil in the orchard was later examined by the Station Soil Chemist, Mr. Wallace, who describes it as follows :—

> "A water-logged tract consisting of a surface layer of peaty material overlying a bed of impervious Blue Lias Clay."

The remaining plum trees in the orchard are not looking healthy and some show signs of infection by *Diaporthe perniciosa*. This is a clear case of trees, whose history is known, becoming enfeebled on account of bad drainage and killed by subsequent infection of *Diaporthe perniciosa*, followed possibly by *Cytospora* sp.

Plate VIII, fig. 1*a*, shows a cross section of the main stem of a young plum tree which was in a dying condition. The roots as in the above case were brown throughout. The tree was uprooted in the summer of 1923. The wood formed in 1923 is comparatively clean as compared with the deeply stained wood formed in the previous year 1922. The brown discolouration is due to the presence of gum in the wood vessels. Gum was present also in the medullary rays and cortical tissues. Discoloured wood of this kind is not invariably invaded by fungus hyphae. The browning of the wood is either the result of the reaction of the plant to the actual presence of hyphae at this point, or due to toxic substances produced by the fungus in tissues lower down on the stem and carried up through the vessels. In either case if the primary cause of the disease is due to infection by one or more fungi, or other organisms, it is more than probable that, after getting such a hold on the plant as to affect the wood formed during the whole of a growing season, the organism would have continued to do so in the following season. The only possible explanation is that the fungus is a weak parasite and its growth in the plant tissues has been checked in 1923 owing to a drastic change taking place in the environment of the plant. This in some cases is undoubtedly correlated with the amount of rainfall. Plate VIII, fig. 1*b* shows this very clearly. The cross section shown is of the main stem of a plum tree, one branch only of which was dead. The roots were examined and only one large root was found to be completely brown. The tree had been grown in the same position in the plantations of the Research Station, East Malling, Kent, for several years. The tree was, through the kindness of Mr. Hatton, cut down for examination in 1923. It will be seen that the disease had been present for some years. It is, significant, however, that during one year, namely 1921, the tree formed more and cleaner wood than in any other year. It is common knowledge that in the year 1921, the summer in England was exceptionally hot and dry. Plate VIII. fig. 1*c* is a cross section of the main stem of a young plum tree which again shows the seasonal activity of the disease.

Several plum trees have been examined and found to be in an advanced stage of the disease and the roots have been found on cutting to be clean and healthy looking. This was particularly so in the case of plum trees brought in from another fruit farm in the Evesham district. The trees were growing on light gravelly soil on a hill. In a normal year the soil dries out to a considerable depth in the summer. It is well-known as one deficient in potash and in consequence the apple trees in the plantation suffer from serious scorching of the leaves. Plum trees of seven or eight years old can be shaken from one side to the other with one hand. Unpublished experiments with willow cuttings by Wallace and Hutchinson at the above Station indicate that there are considerably more fibrous roots produced by plants growing in nutrient media containing potash than are produced by those grown in a medium deficient in potash salts. It is easily understood, therefore, that trees growing in gravelly soil deficient in potash cannot possibly produce a root system capable of absorbing sufficient moisture from a soil which is liable to dry out in summer. The general health of fruit trees can, therefore, be so seriously lowered, not only by excessive soil moisture due to bad drainage, impervious subsoil, etc., but also by insufficient moisture, whether this be due to the physical texture of the soil coupled with, or independent of, potash deficiency, as to make them susceptible to attack by the weak parasite *Diaporthe perniciosa* and possibly other organisms. So far as the root system of a plant is concerned the effect of a waterlogged soil and a soil too dry is physiologically very similar. In the first case waterlogging asphyxiates the roots so that they are unable to function as absorbing organs ; in the second case the roots are possibly killed through excessive dryness and in any case they cannot absorb moisture from a soil which has become dessicated beyond a critical point. As already stated, the disease becomes active in the summer, but the pot plant damaged by sulphate of ammonia and alluded to above contracted the disease early in June after the second crop of leaves had appeared. The production of a second crop of leaves drained the shoot of its reserved food material which further lowered the plant's vitality and before it recovered as the result of leaf and root activities the plant contracted the disease. The progress of the disease in this plant was extremely rapid once it started. Miss Cayley (2) states, and Plate VIII, fig. 1*a*, *b* and *c* corroborates this view, that " infection occurs a considerable time—in some cases probably years —before any definite external symptoms can be seen ; but that, once wilting has occurred, the affected areas die very rapidly. . . ." The reason for this is due in the first place to some physiological factor which upsets the metabolic balance of the tree so that *Diaporthe perniciosa* becomes parasitic. This infection further weakens the plant and usually the cambium is killed within a certain area. Progress of the disease is checked by change of conditions due to change of season or rainfall. The following year, or possibly longer, conditions again

become unsuitable to the plant and the fungus continues growth as a parasite. The rapidity of the advance made by the fungus depends on the degree of unsuitability of the conditions under which the plant grows. In the summer transpiration is at its maximum because the plant is in full leaf. The roots of trees growing in either too wet or too dry conditions from any cause cannot absorb sufficient to keep up the claims made on them by the transpiring leaves and the fungus under these conditions is able to kill further areas of cambium. The death of more and more cambium, and of wood in the same region, from year to year narrows down the conducting channels between root and shoots in an upward and downward direction. The effects of the primary and secondary (*Diaporthe perniciosa*, etc.) causes of the disease are therefore accumulative from year to year until a point is reached when the plant is so enfeebled that *Diaporthe perniciosa* can grow as a parasite much more rapidly with the result that the last stages of the disease are far more rapid than at the beginning.

Several plum tree branches were artificially infected with Silver Leaf (*Stereum purpureum*) for experimental purposes in the late summer of 1923. In the case of one tree a large branch contracted the " Die Back " disease in 1924, after the leaves had become silvered. Here is a case of the parasite *Stereum* weakening a branch to such an extent that *Diaporthe perniciosa* is able to cause a secondary disease. Mr. Nattrass informs the writer that he has observed similar cases elsewhere where Root Rot caused by *Armillaria mellea* was the first cause of disease.

On Young Plum Stocks.

The disease is often present in young stocks before any budding or grafting is done. An interesting and convincing case occurred at Long Ashton this year. The stocks (variety Blaisdon Red) were bought and planted out in rows in the autumn of last year. At the time of planting they were in a very poor condition, although there was no sign of " Die Back " disease present. In the spring of this year some of the plants failed to make any growth at all, whilst the others succeeded in doing so. Early in the year some of the failures were pulled up and thoroughly examined. The stem tissue was clean and healthy looking, but the stub below ground was brown and no sign of new root formation. Later in the summer another lot of the plants which had produced no growth were examined and found to have made no new roots. The stems were dead and the bark covered with fructifications of *Cytospora* sp., *Myxosporium corticolum* and *Diaporthe perniciosa*. Plate IX, figs. 1 and 2, shows the correlation between the extent of disease and the amount of shoot and root growth. This is a case where the development of the disease has been closely observed, and shows clearly that *Diaporthe perniciosa* and possibly other organisms came in as secondary factors. Plate IX, fig. 1, Nos. 2 and 4, illustrates the checking of the

" Die Back " at the point where new buds have grown out. Plate IX, fig. 2, No. 5, shows very slight development of roots coupled with the production of a feeble sucker and side branch.

The disease gets into young stocks as the result of rough handling and an unfavourable season or soil subsequent to transplanting from the stools or layers. The general practice is to dig up or rip up the young stocks and to heel them in before planting. The stocks take some time and often fail to recover, after planting, from this rough treatment, and *Diaporthe perniciosa* and possibly *Cytospora* sp. and other organisms in the meantime are a distinct source of danger. Where hundreds of thousands of young stocks have to be planted out there is a limit, for economic reasons, to the amount of attention that can be given in transplanting. However, it is far sounder to dig up the rooted stools rather than rip them up. In the former a considerable number of the roots are retained, whereas in the latter they are mostly destroyed. Before planting it is also advisable to go over each bundle and trim up the stub and shoots with a sharp knife, making good clean cuts. Further, it is obvious for a number of reasons that in heeling in care should be taken not to damage the root and shoot with hob-nailed boots.

Another source of danger is in budding and, if the latter fails, in grafting on stocks too soon. This operation, particularly grafting, which for other reasons is a bad practice, is an additional check before the young stock has become established after moving. In some nurseries the stocks, in preference to the scion, are carried up to form the stem in the case of standard and half standard trees. This is sound for three reasons: (i.) It gives the stock time to become thoroughly established. (ii.) The union of stock and scion will not be buried below soil level after leaving the nursery and put in their permanent position. (iii.) The union callouses over more completely and makes a straighter and therefore stronger stem than when budding or grafting is done low down on thick and oldish wood. There is a tendency for trees sent out of the nursery with poor root systems to be planted too deeply to ensure good anchorage. This is done in all classes of soil, and is a dangerous and bad practice in heavy land. Plum and other stone fruit trees should not be planted deeply especially in heavy, wet, and cold soils. Trees so planted take a long time to establish themselves in their new quarters since the whole of the root system must undergo a process of regeneration, and in the meantime *Diaporthe pernisiosa* is a source of danger. New roots must be produced higher up where conditions of moisture and aeration are most suitable for growth. Hatton, Grubb, and Amos (7) working with apple to investigate the effect of depth of planting on the growth of the tree, state that " (i.) the results depends to some extent on the variety of root stock; (ii.) seasonal variations affect the results; (iii.) the four or five inches difference in depth of planting give an obvious demonstration of the better anchorage of

the deeper planted trees." These three points are probably true of plum and other fruit trees and recommendation in regard to the earthing up of young stocks and the planting of young trees must be of a general character. It would be best in all classes of soil to plant as shallow as is compatible with good anchorage. These depths will, of course, differ for light and heavy soils. If the weather in the following growing season is too dry the plants can easily be earthed up. On the other hand, if the plants in the first place are planted deeply and the season is wet the soil cannot very well be removed without damaging the plants and they suffer in consequence. In other words, it is safer within reasonable limits to err on the side of shallow planting of young stock since in dry weather this can be rectified by earthing up.

On Cherry Trees.

Young cherry trees suffering from the " Die Back " disease were examined by the writer in the summer of 1924. The tops were still living and bearing leaves although in a very weak state. The root system was completely dead and brown. Subsequent inspection of the nursery proved the primary cause of disease to be a soil factor. The surface soil was light and sandy, and to all appearance favourable for growing cherry trees. Within six inches in some cases, and a foot in others, of the surface the soil consisted of a mixture of almost pure sand and small and large sand stones. The apple trees showed leaf scorch as well as the gooseberry bushes. There has been a certain amount of neglect in hoeing since a considerable number of roots were damaged and exposed above the surface of the soil. The soil was typical of those which are deficient in potash. The cherry trees still left in the nursery show no sign of " Die Back " disease (no fungus infection) since tests were made with the knife for diseased cortex. The leaves, however, were purplish and more highly coloured than is normal for the time of year, and in many cases the tissues between the veins were drying out. Here is another case where symptoms of abnormality are apparent before the advent of any weak parasite or parasites.

Occurrence of Diaporthe Perniciosa on Fruits.

So far as the writer is aware the fungus *Diaporthe perniciosa* has not been recorded previously in this country as a parasite in the orchard on any kind of fruit. This summer, however, a specimen of Peach fruit was received by the Advisory Mycologist for investigation. The fruit was attacked by a soft rot and on the outside of the rotted area there were innumerable fungus pycnidia. These were identified as *Diaporthe perniciosa* and the fungus was isolated from poured plates of the conidia as well as from the internal diseased tissue. At about the same time the writer collected in the plantation at Long Ashton a few undersized and rotting fruits on apple trees (var. Wellington or Dumelow's

FIG. 1.

FIG. 2.

PLATE IX.

FIG. 1.

FIG. 2.

PLATE X.

Seedling). The fruits were attacked by Scab and a soft brown rot. The rotted portion was studded all over with the pycnidia of the fungus *Diaporthe perniciosa*. Poured plates of conidia were made and the fungus obtained in pure culture. Inoculation experiments through wounds were made on both Wellington and Bramley apples (Plates X, figs. 1 and 2). The fungus produced through a wound a soft brown rot and produced pycnidia (Plate X, fig. 2) on the fruit. *Diaporthe perniciosa* was again isolated from the innermost diseased tissue from the four inoculated fruits and a further inoculation and isolation proved the fungus to be pathogenic. No rot developed in the controls. Recently, diseased fruits of Medlar, sent for investigation, were found to be covered with pycnidia of *Diaporthe perniciosa*. The fungus was isolated from the diseased tissue, as well as from pycnospores. Whether or not the fungus is parasitic on Medlar fruits remains to be proved.

Further Evidence of Weak Parasitism of Organisms associated with the Same and Similar Diseases.

The following extracts from different publications by other workers on the same and similar diseases in trees strongly support the present writer's views in regard to the disease known as " Die Back " in this country with which the fungi *Diaporthe perniciosa*, *Cytospora* sp., and bacterial organisms are associated :—Leonian (13) in his account of an Apple Canker (*Cytospora leucostoma*) in New Mexico, concluded that old and neglected trees are the only ones which can be affected by this organism.

Long (14), working on a disease of Poplars in America, caused by *Cytospora Chrysosperma*, stated that the fungus is a serious parasite under conditions such as the following :—(*a*) On trees which are growing at the outer limit of their range and are therefore in a more or less unfavourable environment ; (*b*) On trees weakened from neglect and lack of sufficient water ; (*c*) On trees severely pruned as in pollarding.

Povah (17), who studied the same disease of Poplars in Syracuse, N.Y., states that *C. Chrysosperma* attacked Poplars weakened by fire.

Moss (16), who investigated the disease caused by *C. Chrysosperma* in Ontario states that :—" Younger trees of *Populus deltoides*, especially if seriously injured or weakened, are likely to succumb to the attacks of *C. Chrysosperma*."

Rolfs (18), on Peach trees :

" The age and physical condition of the tree have a marked influence on the extent of injury done by the fungus. Young vigorously growing trees are not seriously injured by it. On the other hand, old neglected trees, especially those standing in sod, are sometimes permanently injured. The real source of danger lies in its attacks on weakened or injured trees, especially those injured by frost."

"Frost, impoverished soil, wet land, lack of moisture, too deep planting, lack of cultivation, wind, fire, or anything which weakens or injures the tissues of the trees aid the organism more or less in its advancement."

Similar evidence can be obtained in the following papers:—Hubert (12), Hahn, Hartley, and Pierce (6), Hahn (7), Stevens (19), and Hemmi (10).

General Consideration.

It would appear that all or any of the organisms, including the fungi and bacteria which are found in trees suffering from "Die Back" disease, can only become pathogenic after the vitality of the tree has been lowered on account of some physiological disturbance, it is next important to consider what are the factors which cause these internal disturbances within the plant. Some of these have already been partly discussed, namely, excessive soil moisture and insufficient soil moisture. The relationship between soil moisture and the growth of plants is a big question and it cannot be fully discussed in the present paper. In England, however, as in other countries, the soil is very variable in character, not only in different districts, but often within a small area of an acre or less. Furthermore, the amounts of moisture in these different types of soils varies according to whether the season is dry, medium or wet. It is evident, therefore, that in soils which normally become very dry in summer, a wet season is advantageous to the plants growing in such soils. Those soils which are normally wet throughout the year improve so far as the plants are concerned if the summer is dry, as in 1921. In an abnormally wet year, such as the year 1924, soils whose moisture is normally within the range of the plant's tolerance become too wet and the plants suffer. Thus a dry season might check the progress of "Die Back" disease in some soils, whilst in others the disease progresses rapidly. Apart from the physical nature and condition of a soil—the growth of a plant is also dependent on the chemical nature of the soil. Some contain an excess or insufficiency of lime; others are deficient in available nitrogen, potassium, or phosphates. Excess or deficiency of any of these chemicals affect the general health of the tree to different extents. In some cases it is extremely difficult to decide what is the factor which affects the growth of the plant. In others the symptoms of the plant are helpful, e.g., Leaf Scorch, Chlorosis. A good many troubles can be avoided by judicious, regular and complete manuring, and a good many can be brought about by neglect of manuring or unbalanced manuring. It needs but little experience to recognise by the tree itself whether it is being overfed or underfed. In addition to carrying a good crop of fruit a tree should make a fair amount of new shoot growth. If this is not done then it is evident that manuring is necessary. On the other hand, if a fruit tree makes strong new shoot growth year after year and bears no fruit it is equally evident that the tree wants to be checked (e.g., by ringing, light pruning,

clamping, or transplanting) to throw it into a fruiting condition. The amount of manure to be given afterwards will be decided by the amount of fruit borne and the growth made. If unmanured fruit trees are allowed to bear heavy crops year after year very little new growth will be made, the fruit will be small and the general health of the tree is so lowered that sooner or later it will succumb to one or more diseases.

Most fruit trees are subject to attacks by insects and fungi and often conditions which favour one may suit the other. A well-known example of this in England is Brown Rot and Aphis attack on plum and other fruit trees. It is common knowledge amongst growers that a bad attack of Aphis and Brown Rot not only may cause complete loss of the crop in the year of attack, but also in the following year and possibly the next. The check to the trees is, therefore, of a very serious nature. During the period which elapses between the attack and recovery the tree is in a low state and it is extremely probable that organisms such as *Diaporthe perniciosa, Cytospora*, etc., can, under such conditions, cause further serious damage to the trees.

In some seasons some varieties of plum trees produce a second crop. This is an unusual procedure for plum trees, but an unusual behaviour of any plant is merely the usual reaction to unusual conditions. In other words, plants never do anything unusual or abnormal, strictly speaking, but are true to their habit by reacting to unusual conditions. Thus a tree does not produce a heavy single crop or a second crop because it is going to die or be weakened, but rather the cause of death or weakening is such that the normally behaving plant produces a heavy or second crop. A sudden, serious, but temporary check in the growing season sometimes causes fruit trees to bear a second crop. The production of this second crop drains the plant of its reserved food material which cannot possibly be replaced in the short period between the removal of this second crop and leaf fall and dormancy.

It is often desirable to head back trees, or to remove large branches for the purpose of thinning. Some kinds of fruit trees can withstand this form of treatment more than others. Nevertheless, there is a limit to which heading back can be done without affecting the health of the tree particularly when large limbs are roughly hacked off or cut through with a saw or other blunt implement (Plate VII, fig. 2). It is advisable after removing a branch with a saw to pare the cut end obliquely with a sharp knife or chisel. Branches should also be removed at the base close up to the mother branch or main stem. After paring off, such large wounds should be treated with a wound dressing all over and freshly pared again round the outside edge so that the inner bark (cambium) is left cleanly cut and in the best condition for quick callus formation.

Hatton (9) finds that different stocks affect the growth of the scion in different ways such as the following :—

(A) Some impart vigour. (B) Some have a slight dwarfing effect. (C) certain stocks accelerate the actual time of blossoming whilst others delay it. (D) under the conditions at East Malling some have a firmer anchorage than others. (E) Some stocks seem to show what is described as incompatabilities with certain varieties, whilst for other varieties they may be good stocks. In some cases either buds fail to make in any quantity or sometimes established trees break away at the point of union.

In view of these effects of different stocks on the growth and general behaviour of the scions worked on them, it is possible that a variety worked on one stock may be more susceptible to " Die Back " disease than others. This point is under investigation at the present time at Long Ashton. The remarks given above in regard to the views of some continental workers on cherry " Die Back," and the effect on time of blossoming found by Hatton (9) is extremely interesting. Some German workers, already mentioned, stated that late spring frosts was the pre-disposing factor to " Die Back " in cherry. It is possible that the use of stocks which delay the time of blossoming, in districts liable to suffer from late frosts might be an important factor in the extent to which the disease would occur under those conditions.

Control.

It is generally accepted that healthy vigorous trees are less liable to succumb to disease than those in a weak condition, but so far as " Die Back " disease is concerned a study of the conditions under which the plant grows is all-important before any treatment can be recommended. The predisposing cause may be due to any one or more of the factors mentioned above and these by no means exhaust the number which can bring about lack of vigour in fruit trees. Growers troubled with " Die Back " in their fruit trees are strongly advised to consult a specialist in the subject of plant diseases because by so doing they will often be able to avoid very serious losses in their plantations. It is futile to attempt to fight the fungus by direct methods once it has gained entrance into the plant. To remove dead and diseased tissue, if in the main stem and it usually is, means killing the tree. Even if it were possible to removed diseased tissue without killing the plant this would by no means cure the disease. On the other hand, the disease can, in the majority of cases, be prevented and checked by the elimination of the primary and fundamental cause or causes which predispose the plant to disease.

In conclusion I wish to express my thanks to Prof. Barker, Director of the above Station, for his constant and kind direction ; to Miss E. M. Wakefield of the Herbarium, Kew Gardens, for identifying and checking the identification of some of the fungi mentioned in this paper; to Dr. G. H. Pethybridge for his kindly criticism and helpful suggestions in regard to the arrangement of the

paper before publication ; to Mr. W. Camps of the above Station for taking the photographs sometimes at short notice and personal inconvenience.

Summary.

1.—The Superficial Bark Canker Disease known and originally described in America, and caused by the fungus *Myxosporium corticolum* Edgert., is constantly present in this country on apple and pear trees twenty years old or more.

2.—The damage caused by it in this country is negligible and it does not require any treatment. There is even a possibility that, in some cases, the activities of the fungus are beneficial.

3.—The supposed Bark Canker Disease as described previously in this country and also attributed to *Myxosporium corticolum* Edgert. occurs only on trees which are already in a weak condition. It is in reality due to the weak parasite *Diaporthe perniciosa* Marchal, which becomes pathogenic only on trees already weakened by other causes.

4.—The fungus, *Diaporthe perniciosa*, is of common occurrence as a weak parasite on fruit trees, having been found to produce a form of " Die Back " in stone fruits as well as on the Apple and Pear. The Bark Canker Disease is the type of " Die Back " which is caused on the apple.

5.—The organisms found associated with " Die Back " of stone fruits are *Cytospora* sp., *Myxosporium corticolum* Edgert., *Diaporthe perniciosa* Marchal, and rod shaped bacterial organisms.

6.—There is strong evidence that none of these organisms is the primary cause of trouble, and that *Diaporthe perniciosa* and in some cases *Cytospora* sp. are weak parasites. The stronger of the two weak parasites in the majority of host plants, is *Diaporthe perniciosa.* Neither can cause disease in a sound and healthy tree and infection by either or both is only possible after the tree has become sufficiently enfeebled on account of one or more physiological factors, e.g., excessive or insufficient soil moisture.

7.—The disease, so far as present knowledge goes, cannot be satisfactorily controlled by direct action against any or all the organisms associated with the disease. It can, however, be prevented and checked by the elimination of the factor or factors which so enfeebled the plant as to render them susceptible to disease by weak parasites.

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Explanation of Plates.

Plate V.

Fig. 1. Upper portion of Apple branch (James Grieve) affected with "Die Back."

Fig. 2. Lower portion of same branch which shows that the "Die Back" is confined to the area above the large Nectria Canker.

Plate VI.

Fig. 1. Superficial Bark Canker (*Myxosporium corticolum* Edgert.) on main stem of standard apple trees.

Fig. 2. "Die Back" on young apple tree, showing acervuli of *Myxosporium corticolum* on bark of affected region.

Plate VII.

Fig. 1. Branch of Cherry Laurel with "Die Back." Cut end shows wedge shaped region of affected wood. Pycnidia of *Diaporthe perniciosa* on bark.

Fig. 2. Another view of same branch, showing the pruned end at which infection took place.

Plate VIII.

Fig. 1 (*a*, *b*, and *c*) shows the effect of season on the development of "Die Back" disease. Sections of Plum trees.

Fig. 2. (*a*) The "a" spores of *D. perniciosa* × 900.
(*b*) The "b" spores of *D. perniciosa* × 540.
(*c*) The pycnospores of *Cytospora* sp. × 1000.
(*d*) The conidia of *M. corticolum* × 300.

Plate IX.

Fig. 1. (1) Healthy plum stock (Blaisdon Red).

Fig. 1 (2, 3, and 4). Plum stocks (Blaisdon Red) showing various stages of "Die Back" disease. Note poor root systems.

Fig. 2. (5) Blaisdon stock very badly affected with "Die Back" disease.

Fig. 2. (6, 7, and 8) Blaisdon stocks killed by "Die Back" disease. Fructifications of *D. perniciosa* and *Cytospora* sp. on bark.

Plate X.

Fig. 1. Two Wellington (Dumlow's Seedling) apples artificially infected with *D. perniciosa*. 20 days after inoculation.

Fig. 2. Two Bramley's Seedling apples artificially infected with *D. perniciosa*. 20 days after inoculation. The fruit on left shows fructifications being produced.

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